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USU AFOSR University Engineering Design Challenge Proposal

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UTAH STATE UNIVERSITY

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Final Report

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- First Semester: conceptual design, preliminary design, critical design review, design justification, drawing package.
- Second Semester: design fabrication, design testing and design evaluation.

The course is team taught by two faculty members who used the design approach used by NASA and by the Department of Defense. Each design team consisted of 7-14 students depending on the complexity of the design challenge.

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FINAL PERFORMANCE REPORT
FOR
GRANT FA9550-11-1-0326, "USU AFOSR University Engineering Design Challenge Proposal
September 30, 2011 – September 29, 2014

Principal Investigator 2011-2012: J Steven Hansen, PhD

Principal Investigator 2012-2014: Byard D Wood, PhD, PE

ABSTRACT
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INTRODUCTION
Based on its proposal to AFOSR in April 2011, Utah State University (USU) was selected to participate in the 2012, 2013, and 2014 AFRL University Design Challenge Program that included 16 universities from throughout the US plus three military academies. Each year AFRL selected a different real world challenge in its effort to help the Air Force solve critical problems. The three design challenges covered in this final performance report were:

Period of Performance	Design Challenge
Academic Year (AY) 2011-2012	The intent of this project is to design a climbing assistance system for the typical warfighter without the use of a grappling hook. US troops that are involved in various rescue and assault operations may be required to scale vertical or near-vertical obstacles in high-risk, non-permissive environments. The design of a system that allows scaling buildings or mountain faces under a variety of conditions in an efficient and effective manner is the desired result. The system should have the following characteristics: • Ability to accommodate troops and their gear, approximately 300lbs • Capability to climb rock faces and concrete/adobe walls • The ability to ascend 60ft or taller surfaces that are vertical or near vertical. • Rate of climb should be faster than 0.1 m/s. • The system should weigh less than 100 lbs and fit in a backpack and carried by a single troop.
Academic Year 2012-2013	USAF Special Tactics Battlefield Airmen executing rescue and assault operations around the world have experienced difficulty traversing irrigation

canals, moving from one rooftop to another, crossing minefields, fast flowing mountain streams, snow and glacier crevasses, desert rock formations, unstable/collapsed structures, and compound walls. These obstacles typically range from one to twenty feet wide and have landings at different elevations.

Solutions to this problem should be light weight, have a multipurpose role (could be used for something other than a bridge), be easy to deploy (i.e. while wearing winter or tactical gloves), reusable, and easy to maintain (e.g. field repairable). It needs to be reliable, strong, and stable, so a soldier weighted down with gear or possibly carrying an injured person (i.e. total weight of 350 lbs) can safely traverse the obstacle.

Academic Year 2013-2014

The requirement is to lift building structures, aircraft, and armored vehicles ~45k lbs on uneven and sloping, wet, slippery, muddy, rocky, sandy (or a combination of) terrain to extricate equipment and personnel in situations where the scene is actively on fire or burnt and have exposed sharp metallic surfaces and oils and lubricants on the ground. The current constraint is the inability to make kits available in small enough volume and weight factor;

The system should have the following characteristics:

- Capable of being set up and employed rapidly
- Standoff controllable lift capability to increase/decrease load height
- Low operating pressure (if using a pneumatic solution)
- Operational in varying extreme cold/hot temperatures
- Operational at high altitude (minimum 10k MSL)
- Operational when exposed to various hazards such as aircraft/vehicle wreckage and must be able to withstand puncture/fire hazards during operation

USU APPROACH

USU’s participation in the AFRL University Design Challenge was accomplished via the Mechanical and Aerospace Engineering (MAE) senior level capstone design course. The mechanical engineering BS curriculum includes a capstone design experience for all of its graduates. This two semester course includes the following design phases:

- First Semester: conceptual design, preliminary design, critical design review, design justification, drawing package.
- Second Semester: design fabrication, design testing and design evaluation.

The course is team taught by two faculty members who have managed/supervised numerous RD&D design projects. Each design team consists of 6-14 students depending on the complexity of the design. Each team can select from a list of design challenges provide by the instructors. The design challenges are sponsored by companies, organizations, individuals, faculty research projects, and the MAE department.

All of the students have successfully passed all of the core mechanical engineering courses as a prerequisite for the capstone course. Each student will spend at least 200-300 labor hours over the two semesters.

The design approach that is taught in the MAE Capstone Design Course is the one used by NASA and by the Department of Defense. This approach is applicable to engineering or science driven hardware, software, and multidisciplinary design projects. There are six phases spread over two semesters with a detailed design of a prototype being done the first semester and the building, testing and evaluating of the prototype being done the second semester. There is a strong emphasis on teams and working in teams.

The project phases include:

<u>First Semester (Design phase)</u>

1. The **Design Definition** (2 weeks)
2. The **Conceptual Design** with an informal review (2 weeks)
3. The **Preliminary Design** with a formal review and evaluation (4 weeks)
4. The **Detailed or Critical Design** with a formal review and evaluation (6 weeks)
    - Fill in all of the engineering details for the design to verify that it meets requirements
    - Develop detailed drawings
    - Deliverables:
        i. Formal Critical Design Review
        ii. Critical Design Review PowerPoint
        iii. Formal written Design Report
        iv. Complete drawing package

<u>Second Semester (Build and test phase)</u>

5. The **Manufacture and Building** of the prototype with a status review (7 weeks)
6. The **Performance Evaluation** with a formal final review and customer acceptance (7 weeks)
    - Test the prototype to verify that it meets the design requirements
    - Deliverables:
        i. Testing report
        ii. Prototype presentation and demonstration
        iii. As-built drawing package

The AFRL Design challenge was assigned to two different teams. The teams were discouraged from talking with each other until after the critical design review. The intent was to create an internal design competition, since each team knew that only one design could represent the University at the completion.

ACCOMPLISHMENTS YEAR 1 (AY 2011-2012) - CLIMBING ASSISTANCE SYSTEM

As stated previously USU had two teams that independently developed a solution to the design challenge. However, USU decided to merge the two solutions into one solution. The result was that the USU team took first place in the competition. The following individuals were members of the wining team.

ASCENDING AGGIES (National Champions)

Row 1 L-R: Daniel Aguirre, Trevor Park, Mark Ortega, Bobby Johnson, James Robbins, and Alyssa Wahlin
Row 2 L-R: Michael Deakin, Jordan Stott, Garrett Vaughan, Steven Daniels, TJ Morton, Tyson Burtenshaw, Rhet Astle, and Keith Bates
Row 3 LR Faculty Advisor Steve Hansen and Faculty Advisor Byard Wood
Not Pictured: Vall Callisaya and Berk Demirgok

Their design presentation that was given to the AFRL Judging Panel is given in Appendix A.

ACCOMPLISHMENTS YEAR 2 (AY 2012-2013) – PORTABLE BRIDGE SYSTEMS

Two seven person teams (See team photos below) accepted the AFRL design challenge. Although A-Team was selected to represent USU at the competition, team Bifrost was allowed to present and demonstrate its solution. A-Team took first place in the competition. The design presentations are given in Appendix B.

A-TEAM (National Champions)
L-R: Taylor Clawson, Ben Scott, Tasha Davis, Mike Terry, Ruth Miller, Joe Woods, and Clair Hawkins
Not pictured: Faculty Advisors Byard Wood and Dennis O'Hara

Team BIFROST

Top Row L-R: Andrew Ostler, Jens Rodman, and Preston Rich
Middle Row L-R: David Reynolds, Josh Vincent, Mitch Parker, Jeremy Kingsford
Bottom Row: Faculty Advisor Byard Wood Not Pictured: Faculty Advisor Dennis O'Hara

ACCOMPLISHMENTS YEAR 3 (AY 2013-2014) – LIFTING SYSTEM

Two ten person teams (See team photos below) accepted the AFRL design challenge. Although Aggie Life Lifters (ALL) was selected to represent USU at the competition, team All-Terrain Lifting Assistance System (ATLAS) was allowed to present and demonstrate its solution. ALL took second place in the competition. The design presentations are given in Appendix C.

AGGIE LIFE LIFTERS (ALL) (2nd Place Winner)

Front Row L-R: Nick Fluehe, Chris Donohue, Marcus Ritter, and Carson Holden
Back Row L-R: Alex Bernkopf, Kyle Mattinson, Derek Shelley, Ryan Clawson, Roger Thorpe, and Hiram Knapp
Not Pictured: Faculty Advisors Byard Wood and Daniel Magda

All-Terrain Lifting Assistance System (ATLAS)
Top Row L-R: Chase Crandall, Dallan Webb, Philip Le Goubin, Nathan Hawkes, and Logan Williams
Bottom Row L-R: Jacob Singleton, Trevor Christensen, Joseph A. Landon, Andrew Gerber, Landon Nielsen
Not Pictured: Faculty Advisors Byard Wood and Daniel Magda

CONCLUDING OBSERVATION

The AFRL University Design Challenge has provided engineering students with a "real world" design challenge that was exciting and meaningful to the Utah State University Mechanical and Aerospace Engineering senior level students. The principal author (Byard Wood) has been involved with student design competitions at three universities extending over three decades. In his opinion, the AFRL University Deign Challenge Program ranks as the very best design challenge for students in a capstone design course for three primary reasons: 1) unlike many of the students design competitions that have the same challenge year after year, a new challenge was given each year so that all teams started with a "clean slate" such that there was not a design legacy that needed improvements, 2) all teams were given the same budget, and 3) AFRL personnel were available throughout the design process to help clarify and provide feedback to the students.

APPENDIX A

ASCENDING AGGIES
Student Design Presentation given to the AFRL Judges
April 20, 2012

Pages 9-19

Utah State University Ascending Aggies

AFOSR/AFRL Design Competition

April 20, 2012

1

Team Picture

2

Design Challenge

- How do we assist a team of four soldiers in climbing a 90 foot wall without a grapple hook?

3

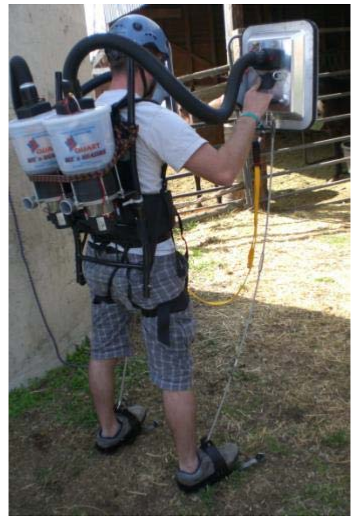
Design Requirements & Goals

- Support 300 lbs
- Ascend 90+ ft surfaces
- Fit inside 3 cubic ft
- Stealth Desired
- Minimal weight desired

4

USU Solution

- Vacuum Ascender
- Adhesive Anchor
- Rope Ascender



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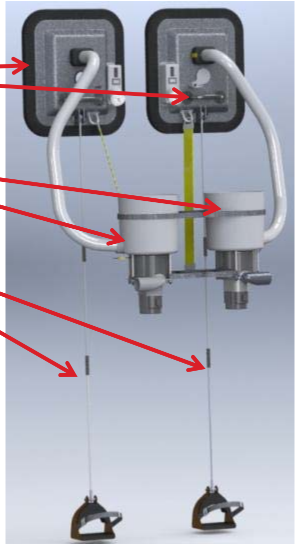
University Design Challenge

1. Team member(s) ascends with vacuum ascender
2. At the top, the team member(s) applies adhesive anchors
3. Remaining team members ascend with rope ascenders

6

Vacuum Ascender

- 2 suction pads
- Vacuum packs
- Support system



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Suction Pads

- Base
  - Aluminum 6061-T6
- Pressure release
  - 2 in. diameter hole
- Instrument panel
  - Analog vacuum gauge, voltmeter, on/off switch
- Handle
  - Aluminum, 7.5 in. wide
- Skirt
  - EVA foam, abrasion resistant
- Friction strip
  - Stealth Rubber

8

Vacuum Packs

- Hose
  - 1.5 in. diameter
- Wiring
  - 16 gauge
- Batteries
  - 5000 mAh and 1.49 lbs/battery
  - 7/vacuum pack
- Vacuum motor
  - 3-stage, 3.8 psi differential, 93 CFM, 6.1 lbs./motor

9

Support System

- Connection Rod
  - 1300 lb tensile load
- Harness/Daisy chains
  - 300lb. rating
- Foot Support
  - Stability and comfort

10

Testing

- Vacuum Ascender
  - Seal Test
  - Support System Test
  - Horizontal Surface Test
  - Motor Test
  - Battery Test
  - Wet Surface Test

11

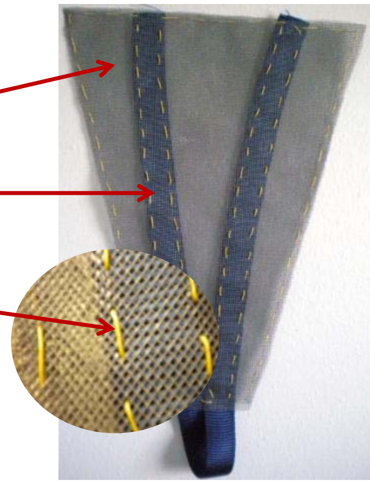
Improvements from Testing

- Toe spikes
- Climbing Ladders
- Pressure Release

12

Adhesive Anchor

- Special T CA Glue
- Fiberglass Mesh
- Nylon Webbing
- Grade 49 Kevlar Thread

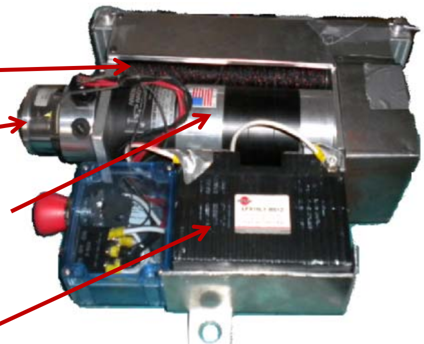


Adhesive Anchor (2)

- Tested to hold at least 360 lbs.
- Shear Strength
  - 870.2 psi – 2901 psi

Rope Ascender

- 1/8 in. Technora rope
- Winch style
- Brake Feature
- 609 in. lbs. gear motor
- Fully Reversible
- Battery powered



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Rope Ascender (2)

- Tested to 300 lbs
- Tested battery life
  - Ascended equivalent of 300 ft.
- Tested rope to withstand wear of climbing

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Safety Features

- Vacuum Ascender
  - Vacuum gauge
  - Voltmeter
  - Recessed on/off switch
  - Harness/daisy chains
- Rope Ascender
  - Reversible
  - Emergency stop button to engage brake

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Design Meets the Requirements

- Supports over 300 lbs
- Ascends 90+ ft surfaces
- Fits inside 3 cubic ft
- Stealth achieved in glue pad and rope ascender
- Minimal weight desired, with an overall solution weight of 132 lbs
  - 33 lbs per soldier (4 soldiers)

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Concept of Operations

3 Steps:

1. Team member(s) ascend the wall
2. Team member(s) attaches glue pads
3. Remaining team members simultaneously ascend

Climbing a Brick Wall

APPENDIX B

CROSSING THE GAP
A-Team
Break-Apart Mobile Bridging and Infiltration (BAMBI) Device

And

CROSSING THE GAP
BIFROST
Obstacle Crossing Device (OCD)

Student Design Presentations given to the AFRL Judges
April 17, 2013

Pages 20-38

Crossing the Gap

Break-Apart Mobile Bridging and Infiltration (BAMBI) Device

Utah State University
The A-team
Clair Hawkins
Taylor Clawson
Ruth Miller
Ben Scott
Tasha Stembridge
Michael Terry
Joe Woods

1

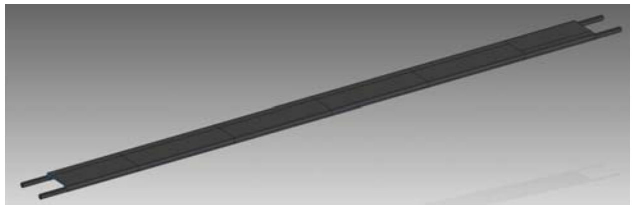
Design Purpose

Enable USAF Airmen to traverse obstacles such as canals, fast flowing mountain streams, glacier crevasses, desert rock formations, and collapsed structures

Able to quickly assemble and deploy

Usable in every climate condition, day or night

2



Design Objectives

Span obstacles of 5 to 20 feet

Under 20 lb.

Hold a 350 lb. static load

Packed volume under 5 ft^3

Multipurpose - perform at least 2 functions

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3

Design Solution
BAMBI

6 sections, each 44 in. long

Walking platform 14 in. wide

Sections secured with Velcro

Ends wrapped in Kevlar and rubber for traction and protection

Textured surface for traction

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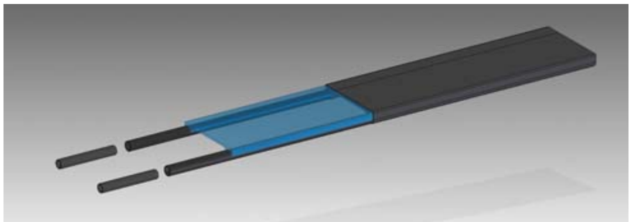

Section Construction

Joint tubes attached with urethane resin

Main tubes epoxied to foam platforms

Foam and main tubes wrapped in carbon fiber weave

Velcro adhered to the bottom side of the bridge

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Joints

High modulus carbon fiber

12 in. long

1.6 in. outer diameter

Twice as thick as main tubes (0.11 in.)

Set of joints yields at a moment greater than 1750 lb.-ft.

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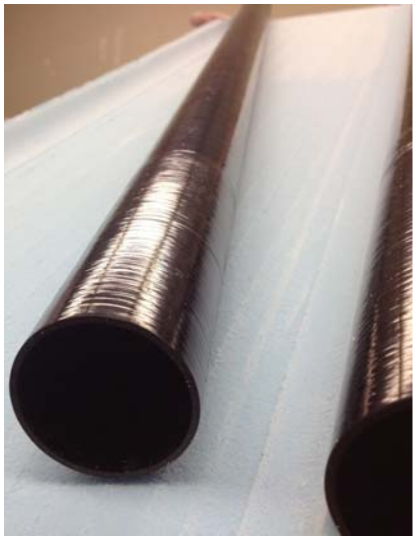

Main Tubes

High modulus carbon fiber

44 in. long

1.75 in. outer diameter

Thickness varies between 0.07 and 0.08 in.

Ends are reinforced with extra hoop layers

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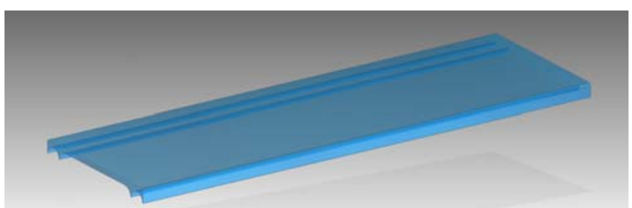

Platform

44 in. long and 14 in. wide

STYROFOAM™ brand Hi-Load 40 foam board

CNC used to shape foam for precise fit

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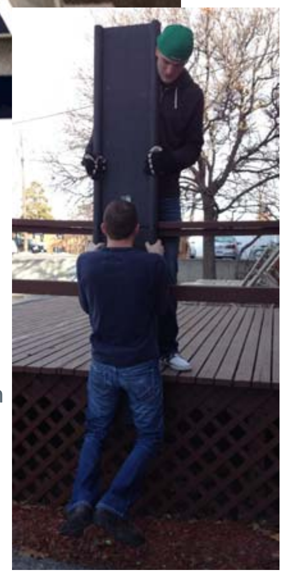


Velcro

Extreme™ Velcro

13 x 2 in. strips

Prevents platforms from separating under load

Holds 5x required axial load with dirt accumulation

9

Feet

Ends wrapped in Kevlar & encased in rubber

Protects from impact and sharp objects

Provides traction on various surfaces

10

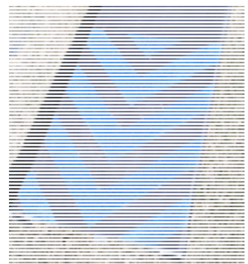
Walking Surface

Sand bonded to carbon fiber with epoxy for strengthened bond

Chevron pattern

Adds traction in inclement weather

Allows use on steep inclines



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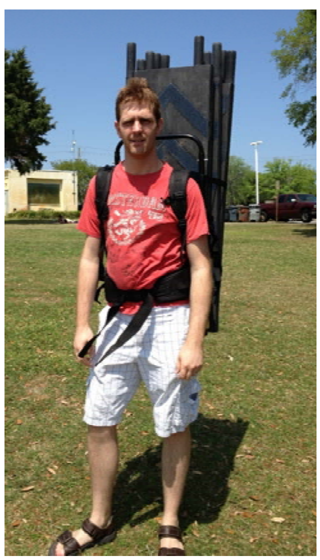

Portability

Can be strapped to any backpack

Weight can be dispersed among multiple users

Platforms don't require protective covering

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12

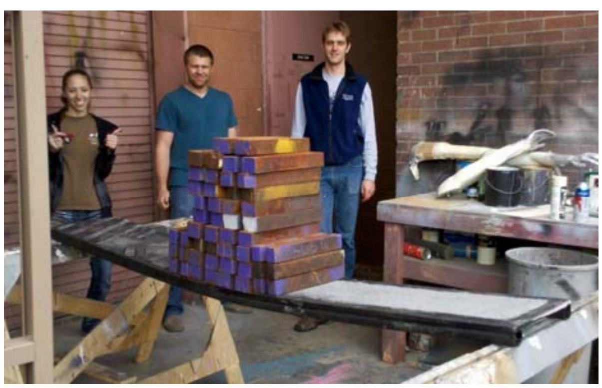
Extra Features

Can be used to climb structures up to 15 ft. high

Self leveling on mildly uneven surfaces

Usable as a stretcher

13



Component Testing Results

Component	Design Requirement	Actual Failure Point
Main tube	Withstands a moment of at least 875 lb.-ft.	1031 lb.-ft.
Joint	Withstands a moment of at least 1750 lb.-ft.	2042 lb.-ft.
Velcro	Holds an axial load of at least 40 lbs.	Greater than 200 lbs.

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Deflection Testing

Total deflection of 14 in. with a 350 lb. central load

Deflection caused primarily by tolerances in joints

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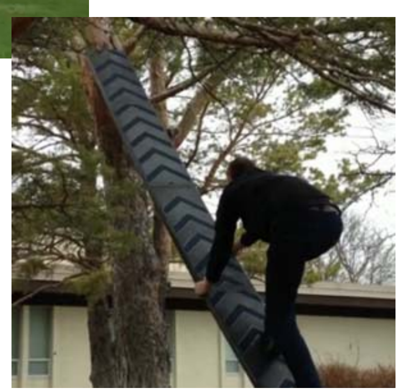
Field Testing & Training



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Total Weight	27.2 lbs.
Packed Volume	3.95 ft^3
Variable Span up to	20 ft.
Easy to use	
Short deployment and retrieval time	

BAMBI Summary

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Cost Analysis

Research and Development Costs

Total Hours			~1400
14-Jan	Texas Almet	Aluminum honeycomb	$334.12
17-Jan	Rockwest Composites	2.625" CF tubing	$448.59
29-Jan	Reliable Source	36" aluminum tubing	$545.00
23-Jan	IPACO	Steel for jig	$23.37
24-Jan	IPACO	U-bolts	$14.92
7-Mar	Strapworks.com	Aluminum buckles	$19.37
Subtotal			**$1,385.37**

Material Costs

28-Jan	Alumilite	Rubber	$171.30
22-Feb	TMI	Epoxy	$107.82
19-Feb	Home Depot	Foam board, acetone	$41.68
23-Feb	Home Depot	Sandpaper, lumber, paint liner	$51.87
4-Mar	HD Supply White Cap	Foam board	$188.24
7-Mar	TMI	Epoxy	$115.21
26-Mar	Archeo-Tectura	Foam CNC	$470.00
	Toray	M40j	$1,261.00
	Ben Scott	Travel to Northfork	$576.00
	Lowes	Layup supplies	$108.51
23-Mar	Home Depot	Velcro	$62.24
1-Apr	Home Depot	Vacuum tape	$5.23
2-Apr	Home Depot	Duct tape, painter tape	$24.11
Subtotal			**$3,183.21**

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Weight and Volume Breakdown

Weight Summary

	Weight(g)	Weight (lb)
Section 1 (End)	2108	4.6
Section 2	2065	4.6
Section 3 (Thick Joints)	2105	4.6
Section 4 (Thick Joints)	2133	4.7
Section 5	2071	4.6
Section 6 (End)	1869	4.1
Total	**12350**	**27.2**

Packed Dimensions

Length (in)	44.75
Width (in)	16.5
Height (in)	9.25
Volume (ft^3)	**3.95**

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Future Improvements

- Optimize feet for lower weight
- T1000 carbon fiber
- Optimize foam thickness
- Manufacturing technique

AFRL COMPETITION DESIGN BRIEFING

Crossing the Gap

UtahState University

BIFROST

April 16, 2013

Design Objective

- Create a system to safely transport multiple USAF Airmen across various obstacles.
  - Gap Length: Up to 20 feet
  - Maximum Load: 350 lbs.
  - Surface Conditions: Vary with Terrain

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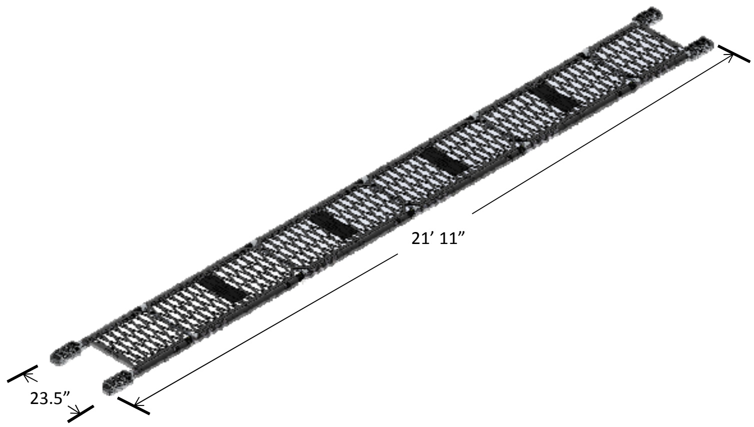
2

Design Solution

- Carbon Fiber Rails with Nylon Web Platform



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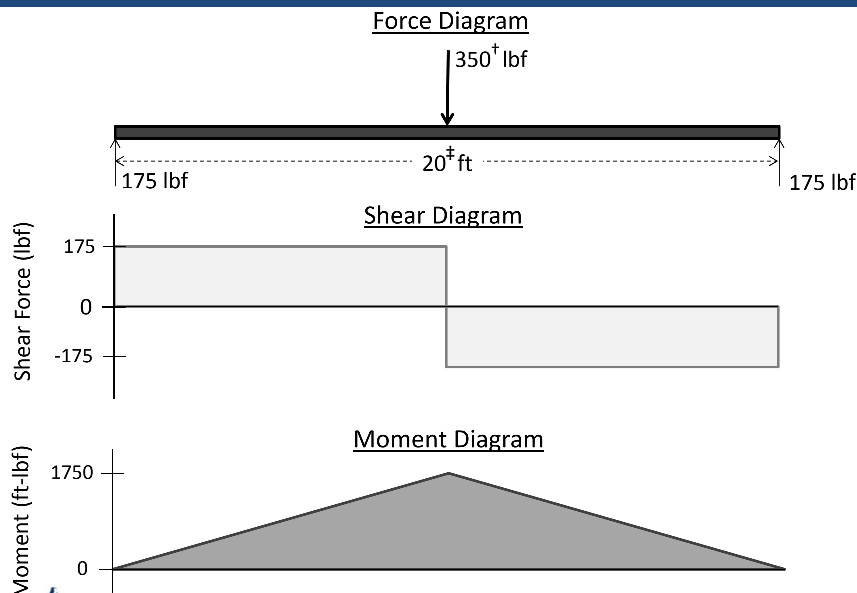
Load Distribution



† - Load Requirement
‡ - Distance Requirement

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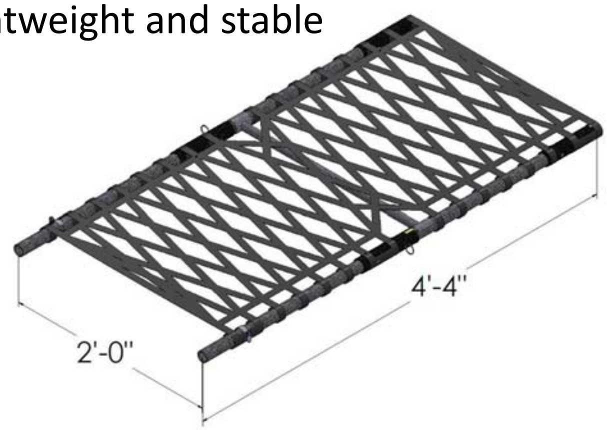
Mesh Bridge Platform

- Versatile – effective in all weather conditions
- Exceptional strength – 900 lbs. break strength
- Lightweight and stable



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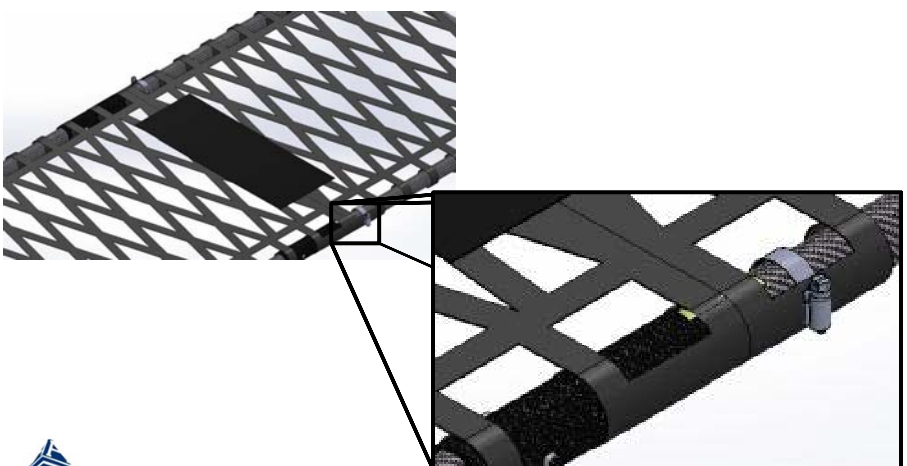
Joining Mesh to Tubes

- Velcro platform sections together
- Bolts and clamps prevent sliding



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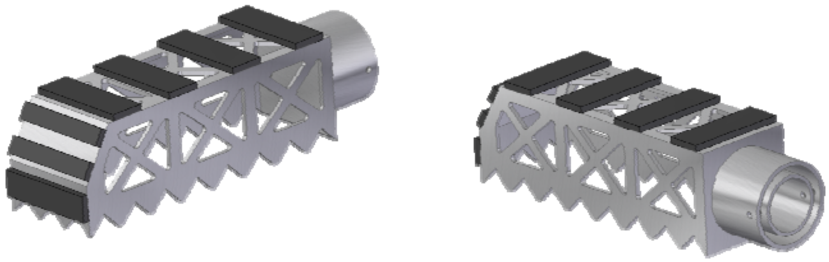
Footing



- Designed to function on multiple surfaces
- Lightweight aluminum
- Universal attachment

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Size When Packed

- Total Volume (3 packs): approx. 2.7 ft^3
- One pack contains: Two 4’ sections, mesh and one tension bar
- Pack Dimensions: 11” X 5” X 24”

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Tension Bar

- Carbon fiber with aluminum ends
- Keeps the mesh in tension
- Provides added rigidity

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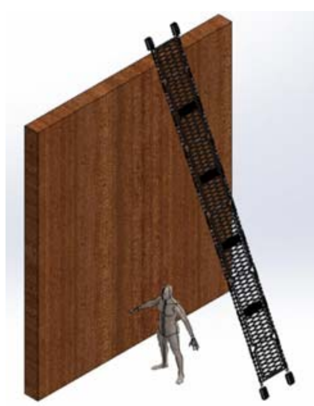
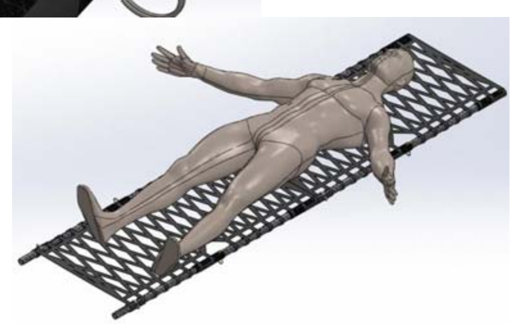
Innovative Features





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Costs

Item	Cost/Unit	Qty	Total Cost
Composite Tubing (Main)	$23.29/ft	40 ft	$950
Composite Tubing (Sleeves)	$26.76/ft	12 ft	$330
Mesh	$0.33/ft	500 ft	$115
Footing	$125 ea	4	$500
Pins	$4 ea	40	$160
Tensioners	$75 ea	5	$375
Misc			$300
Testing			$2500
Total Cost			$5280

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Weights

Item	Weight/Unit	Qty	Total Weight
Composite Tubing (Main)	0.4 lb/ft	40 ft	17 lb
Composite Tubing (Sleeves)	0.5 lb/ft	12 ft	7 lb
Mesh	0.0088 lb/ft	500 ft	7.4 lb
Footing	1.25 lb	4	5 lb
Pins	0.01 lb	40	1.4 lb
Tensioners	0.75 lb	3	3.4 lb
Total Weight			41.2 lb

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Summary

- Gap Length: 4 to 20 feet
- Weight of system: 41.2 lbs.
- Packed Volume: 2.7 ft^3
- Functions: Bridge, Ladder, Stretcher

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Phase II System Advancements

- Improve system connections for increased speed
- Test other carbon fiber layups in order to reduce tube diameter and weight

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14

Questions?

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APPENDIX C

HYDRAULIC LIFTING SYSTEM
Aggie Life Lifters

And

ALL-TERRAIN LIFT ASSISTANCE SYSTEM
Aggies that Lift Armored Vehicles

Student Design Presentations given to the AFRL Judges
April 16, 2014

AFRL COMPETITION DESIGN BRIEFING

Team Picture

Design Objective

- Create a system to safely rescue an injured person pinned under an armored vehicle
  - Vehicle weight: 45,000 lbs.
  - Lift Height: 18 to 24 inches
  - Packed size: 12” x 12” x 6”
  - Weight: $\leq$ 30 lbs
  - Environment

Aggie Life Lifters 3

Utah State University

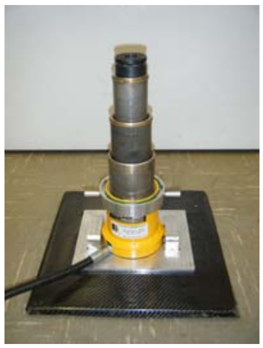
Design Solution

- Telescopic Hydraulic Cylinder & Carbon Fiber Base

Aggie Life Lifters 4

Utah State University

Deployment



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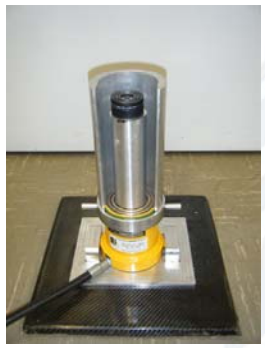

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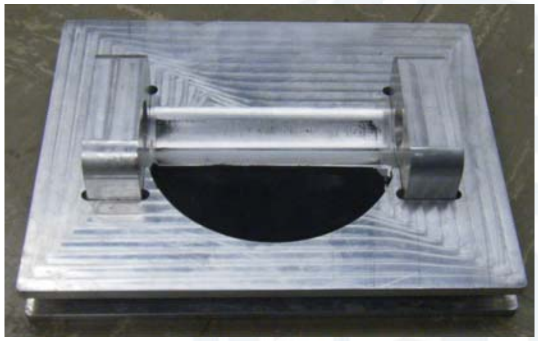
3

Cylinder

- Custom Columbus Jack
- 3 Stage Ram
- 10,000 psi

Base Assembly

- Pivot Design
- 6061-T6 AL
- Flanged for carbon fiber sandwich panel



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Carbon Fiber Base

- 3K tow
- Structural Foam
  - Rohacell

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Pump/Reservoir

- Enerpac Pump
- Rubber Bladder
- 28 V Battery

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C-shore

- Aluminum 6061-T6
- Locking Feature

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Extension and Saddle

- Aluminum
- Locking Feature

Aggie Life Lifters 11

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Innovation

- Cylinder
- Carbon Fiber Base
- Hinge Assembly
- Locking Features
- C-Shore
- Double Acting, Single Port Cylinder

Aggie Life Lifters 12

UtahState University

Testing

- Angled lifting
- Different Soils
- C-Shoring
- Loads above 30,000 lbs
- Extension
- Base Types

Aggie Life Lifters 13

Testing

Aggie Life Lifters 14

Testing

Parts List		
Component	Weight [lbs]	Cost [$]
Base	1.45	176
Hydraulic Cylinder	16.5	2000* Donated for project
C-Shore	3.5	100*
Extension	1.85	200*
Pump/Reservoir	18.8	2670
Hoses	1.85	100
Base Assembly	4.93	700*
Battery	1.5	125
Saddles	1.95	214
Shovel	1.3	13
Total	53.63	6,298

* Estimated cost

Future Improvements

- Different Materials for the Cylinder
- Potentially Eliminate Base Rotation Feature
- Extension and Cylinder Use Same Saddle
- Eliminate the Secondary Pump
- Remote Control for Hydraulic Pump

Summary

Parameter	Requirement	ALL*	Margin 1**
Lift Height	18"	22"	18%
Max Load	45,000 lbs	45,000 lbs	0%
System Weight	<30 lbs	53.63 lbs	-78.7%
Packed Dimensions	12x12x6"	14x14x7"	-58.8%
Operating Pressure	<150 PSI	N/A	---

*Current Best Estimate
**Margin%= [Requirement-Specification]/Requirement*100

Questions?

If you have more questions after the presentation contact Marcus Ritter at marcus.a.ritter@gmail.com

Appendix – FMEA

Hazard	Cause	Effect	RPC	Countermeasures	RPC After
C-shore					
C-shore is not locked properly	User error	If load were to slide or become unstable c-shore could possibly be shot out of place	2	Put stops in the locking mechanism so user knows c-shore is locked in correct position.	3
Buckling	Large incline, small contact area, or uneven contact surface	Large moments induced into c-shore and possible failure of locking clamp and instability of overall system	3	Analyze lifting point to verify if c-shore is safe to use in lifting situation if not use a different shoring method.	3
Locking Feature Shifting	Uneven load on C-shore and not inspected correctly	under large moments c-shore could possible pop off of the top of the cylinder	2	Check that locking clamp bolts are tightened in assembly procedure and in every maintenace check and torque spec	3

FMEA cont.

Hazard	Cause	Effect	RPC	Countermeasures	RPC After
Cylinder					
Cylinder lock up	Side loading	The cylinder would lock and not be able to be lowered	3	Spec the cylinder to a higher max load and make the cylinder capable of rotating with load	3
Cylinder over loaded	Lift a load heavier than the cylinder is rated	Possible rupture in cylinder wall and oil sprays out	3	Pressure release value	3
Leak in the Cylinder	Seals fail	Cylinder pressure goes over max pressure or seal wear down	3	Spec out better seals	3
Carbon Fiber Base					
Crushing	Overloading	Base will push into soil	3	Lay up the base effectively enough so that the aluminum component is in contact with itself.	3
Delamination	Improper layup/ Overloading	Base will fail and system could possibly fail	2	Look for surface defects on Rohacell before layup. Have the system completely vacuum sealed during curing time.	3
Moisture infiltration	Improper layup	Overall base strength might be reuced slightly.	3	Layup correctly by making sure the Rohacell is completely enclosed within the carbon fiber	3
Carbon Fiber Failure	Improper layup/ Overloading	Possibility of complete system failure.	1	Layup correctly of base and regular inspection of the fibers in the base	2
Extension and Saddle					
Crushing	Overloading	Load Falls potentially injuring personal and breaking other items	3	Different material or bigger extension	3
Buckling	Overloading/ Side Load	Buckles and drops load, potentially injuring personal and breaking other items	2	Different material or bigger extension	3
Extension Failing to Lock	Side Loading	Shearing extension off, dropping load and potentially injuring personal and breaking other items	3	Longer internal cylinder to help side load	3
Saddle Shears	Side loading	Potential dynamic load of other items	3	Different material	3
Hose					
Crush / Pinch	Improper Routing	Load Fails to lift	3	Be mindful of hose routing	3
Burst	Overloading/ Damage	Load falls potentially injuring personal and breaking other items	3	Inspect the hose for damage before use	3
Leak	Loose Fittings	Load may slowly fall	3	Check for leaks before use	3

FMEA cont.

Hazard	Cause	Effect	RPC	Countermeasures	RPC After
Pump					
Battery Catches Fire	Short circuit/ Battery Puncture/ Excessive Temperature	Pump no longer works, possible ignition of hydraulic fluid. Could result in minor burns to personnel	2	Put Battery outside of case that contains hydraulic fluid, so if battery catches fire, it is away from the hydraulic fluid Use a rugged battery, and disconnect battery from pump system when not in use. Use a water/glycol type hydraulic fluid that is not flammable.	3
Pump overpressurizes hydraulic system	Internal pump relief valve failure	Fittings or hoses could rupture and leak and spray hyraulic fluid	2	Will install pressure guage in the hydraulic system to allow for operator to visually confirm the system is not exceeding the operating presure (10,000) psi.	3
Aluminum Base					
Base becomes deformed	Load applied greater than design	Use of base becomes severly limited	2	Make a thicker base or don't use for loads greater than design load	3
Base cracks	Load applied greater than design load and/or fatigue	Strength of base is reduced and fracture during operation is	3	Make a thicker base or don't use for loads greater than design load	3
Cylinder Interface					
in breaks off cylinde	Over loading	Cylinder falls over	3	Make pins bigger diameter so they can withstand higher loads	3
Ears break	Over loading	Cylinder falls over	3	Make ears out of thicker materi	3
e breaks under cylin	Over loading	Cylinder falls over	3	Make base thicker	3

All-Terrain Lift Assistance System "ATLAS"

2014 AFRL Challenge
16 April 2014

AGGIES THAT LIFT ARMORED VEHICLES

Overview

- Challenge
- Team
- ATLAS Solution
- Conclusion

2

Challenge

Lift aircraft, and armored vehicles ~45k lbs on uneven and sloping, wet, slippery, muddy, rocky, sandy terrain to extricate equipment and personnel.

The lift kit must be able to create a rescue corridor of 22+ inch height having a secondary function of shoring to hold the load in place.

System should be lightweight and packable to be carried and operated by a single person.

afrlchallenge.org

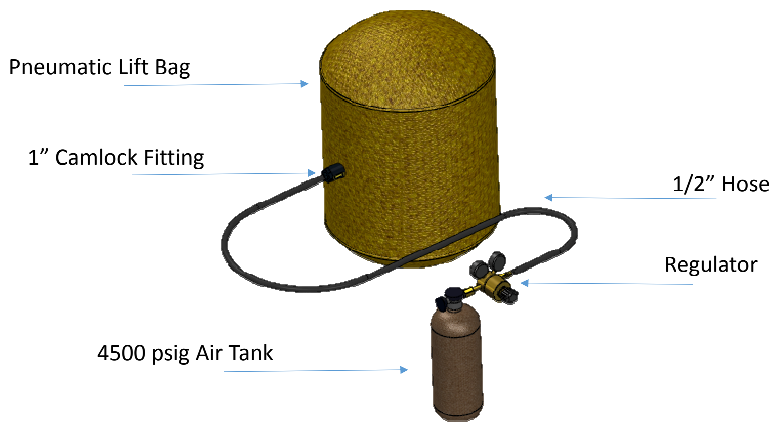
3

Team

Top L-R: Chase Crandall, Dallan Webb, Philip Le Goubin, Nathan Hawkes, Logan Williams
Bottom: Jacob Singleton, Trevor Christensen, Joseph A. Landon, Andrew Gerber, Landon Nielsen

4

Solution - ATLAS



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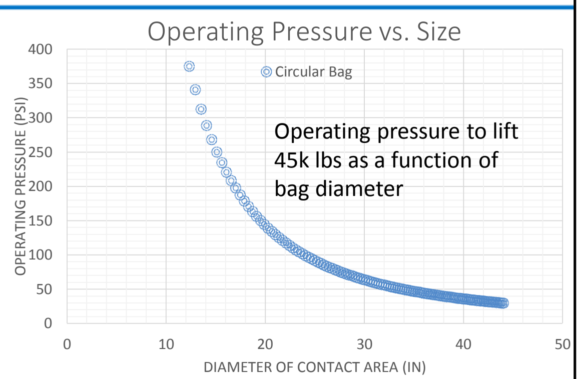
Pneumatic Solution

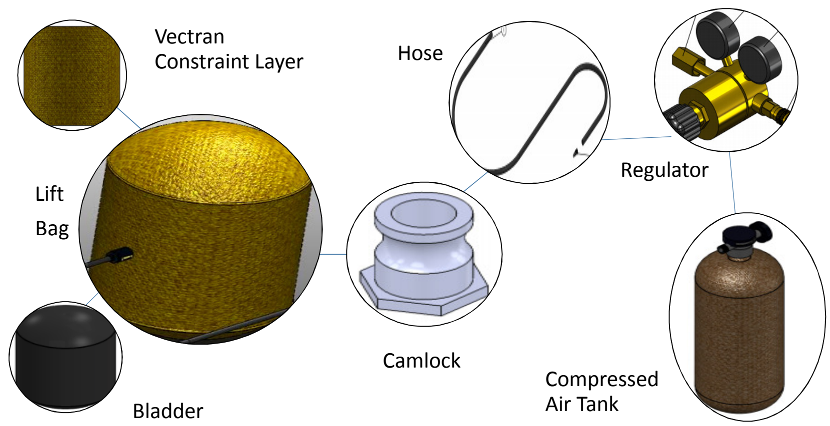
- Lifting capability

Max Load = f(Size, Operating PSI)

- Favorable for different types of surface contact
- Favorable for inclines
- Lightweight and efficient for wide range of lifts
- Currently used by DoD and in industry among Fire Departments and other rescue organizations



Functional Model



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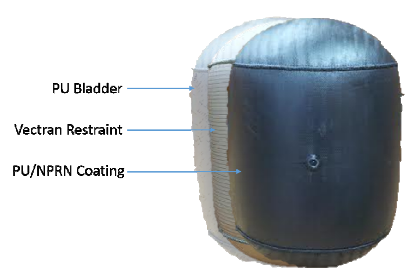
ATLAS Innovations

- High Fidelity restraint Layers
- Low fidelity bladder
- Multiple layers allow more packable concept for larger bag solution



Layer	Material	Function
Bladder	Polyurethane (PU)	Gas impermeable layer for containing air
Restraint	Vectran	Constrain forces in lift system
Protective	PU-Neoprene (NPRN)	Layer protection against sharp surface and temperatures

Testing & Development

- Vehicle loads >30,000lbs
- Lifting heights – 24 in
- Minimum insertion area <3 in
- Inflation/Deflation
- Inclined surfaces
- Lifting configurations
- Vehicle contact areas
- Uneven & soil surfaces

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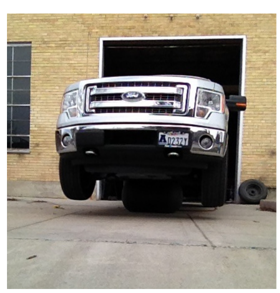
Testing & Development

- Challenges & Lessons Learned
  - Co2
  - Stability
  - Deflation time
  - Safety



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Improvements & Current Design

- Camlock inflation fitting
  - 1 in ID
  - Full inflation ~1 minute
  - Deflation <30 Seconds
- 2 tested configurations for lift
  - Vertical reaches 24 inches
  - Horizontal reaches 18-20 inches
- 4 Layers of Vectran with DSP sleeve for Camlock fitting

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Requirements Summary

Against USAF System

Against Requirements

Parameter	Requirement	AF Lift Bag	ATLAS*	Margin 1**	Margin 2**
Lift Height	18”	20”	24”	33%	20%
Max Load	45,000 lbs	10,000 lbs	34,000 lbs (SF=2)	-24.4%	240%
System Weight	<30 lbs	21.5 lbs	36 lbs	-20%	-68.4%
Packed Dimensions	12x12x6”	8x10x27”	14x12x22”	-328%	-71%
Operating Pressure	<150 PSI	27 PSI	75 PSI	NA	NA
Min Lift Height (Empty)	<3”	3”	2”	33%	33%

*Current Best Estimate
**Margin%= [Requirement-Specification]/Requirement*100

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Future Design Path

- Limits removed from schedule and budget
  - Optimize bag diameter to pressure specifications
  - Optimize inflation stem and hose hardware
  - Trade more materials for bladder and protective layers
  - Reduce inflations system weight by 50%
- Development and Design Focus
  - Approach inflation different then HPA
  - Venturi concept or chemicals

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Conclusion

- ATLAS introduces an new concept to pneumatic heavy lift devices with a major improvement in lifting load and height capabilities
- Students from USU have demonstrated the use of their system on inclined slopes and with a variety of heavy vehicle equipment with fast operating times
- Next step design can improve overall size and weight budgets by >30%

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Summary

- Challenge
- Team
- ATLAS Solution
  - Design
  - Testing & Lessons Learned
  - Current System Design & Operation
- Conclusion
  - ATLAS and requirements summary
  - Plans for further development

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Questions?

Questions can be directed to Jacob Singleton though email:
jacob.singleton@aggiemail.usu.edu

AGGIES THAT LIFT ARMORED VEHICLES

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Supplemental Slides

AGGIES THAT LIFT ARMORED VEHICLES

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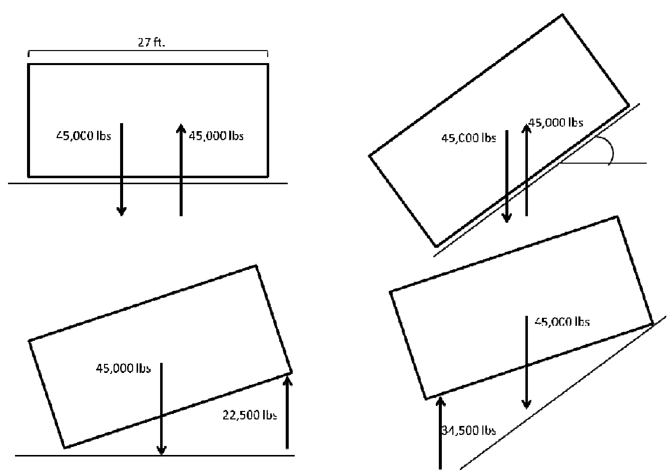
Free Body Diagrams



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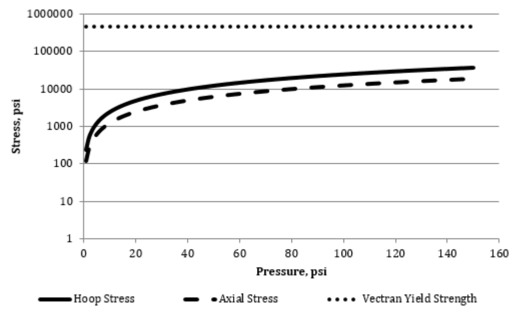
Hoop and Axial Stresses

$$\sigma_{hoop} = \frac{Pressure * Diameter}{Wall\ Thickness}$$

$$\sigma_{axial} = \frac{Pressure * Diameter}{2 * Wall\ Thickness}$$



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Material Trade

Property	Vectran	Kevlar/Aramid	Vectran:Kevlar
Density [lbs/in³]	0.050	0.052	0.962
Tensile Strength [Gpa]	3.2	2.9	1.103
Abrasion Resistance [cycles to failure]	286	83	3.446
Impact Resistance [Energy @ penetration, in-lbs]	125	50	2.5
Chemical Resistant	Yes	Yes	N/A
Heat Resistant	Yes/Chars	Yes/Chars	N/A
UV Resistant	Yes	No	N/A

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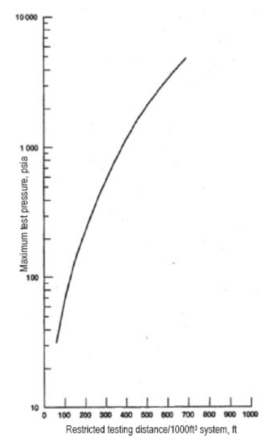
Safe Stand-off Distance

$$D_{Vessel} = \frac{D_{1000} \cdot \sqrt[3]{V_{Vessel}}}{10 \cdot ft}$$

V_{Vessel} = Volume of the piping/vessel/system being tested, ft^3
D_{Vessel} = Safe separation distance, ft
D_{1000} = Safe separation distance for a 1,000 ft^3 vessel per curve above right.

D_{1000}(150psi) = 100ft **V_{Vessel}= 6.28ft^3** **D_{Vessel}= 18.5 ft**



Restricted distance for pneumatic pressure testing

"Pressure Systems Safety," NASA Glenn Research Center, http://smad-ext.grc.nasa.gov/shed/pub/gsm/chapter_07.pdf.

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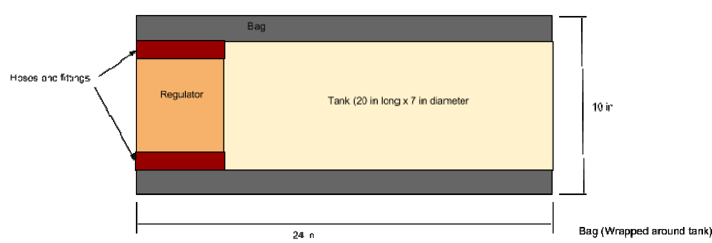
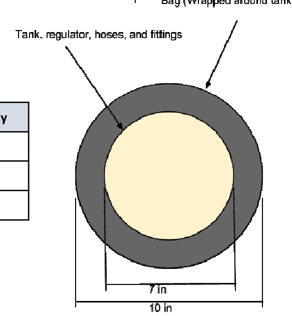
Packing





Requirement	Size	Mass	Lifting Capability
Threshold	12x12x6	30lbs	45,000lbs
ATLAS*	14x12x22	36lbs	34,000lbs
ATLAS**	14x12x22	36lbs	45,000lbs

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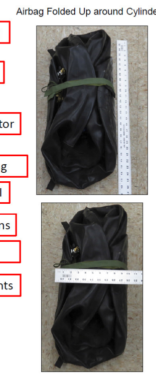
USAF Current System

- Lift Capacity: 10,000lbs
- Lift Height: 20”
- System Weight: <22lbs
- Op. Pressure: 27 PSI
- Packed Dimensions: 8x10x27”



Hazard	Cause	Effect	RPC	Countermeasures	RPC After
Over pressurize air bag	Regulator fails	Load falls and injures rescue personnel	1	Use a pressure gage to test. Regulator incorporates to pressure gauges; one for the tank pressure and one for the output line pressure to the bag. Never lift without shoring if load is smaller than allowable contact area.	3
Over pressurize air bag	Regulator fails	Personnel in blast radius of bag are injured by flying debris	1	Safety margin achieved with robust regulator (5000 psig). Tank is never filled beyond 4500 psig. Personnel will either stand off at safe distance (>18ft) or take cover behind blast shield.	3
Over pressurize air bag	Doesn't unfold properly	Possibility of overpressurinzing the bag	2	Pre packaging folding with "parachute concept." Use a slower inflation time to reduce the risk of bursting the bladder. Also, inflate as much as possible prior to taking load weight.	3
Tank Explosion	Overheat	Personnel in blast radius of bag are injured by flying debris	2	Insulate pressurized tank. House the tank in a package with the lift bag when not in operations and leave in backpack to avoid overhearting. Light colored composite SCBA tank to assist in avoiding high temperatures.	3
Bag Puncture	Sharp Exposed Edges	Load falls and injures rescue personnel	2	Use sand bag placement to protect bag from sharp edges.Place sandbags under load for shoring during lift. If the bag is punctured the load will only fall down on the sandbags. Polyurethane/Neoprene protective coating applied to restrain layer for protection. Pre and post mission inspections for bag defects.	3
Bag Puncture	Sharp Exposed Edges	Personnel in blast radius of bag are injured by flying debris	2	Use sand bag placement to protect bag from sharp edges. Only inflate from safe stand-off distance (>18ft). Polyurethane/Neoprene protective coating applied to restrain layer for protection. Pre and post mission inspections for bag defects.	3
Stability	Slips out from under vehicle	Load falls and injures rescue personnel	2	This will allow for more stable lifting on different inlinces and types of surfaces that may be more slippery. Tow straps assist in vehicle and bag stability.	3
Sability	Bad bag placement	Load falls and injures rescue personnel	1	Inflate bag slowly, and closely monitor the positioning of the vehicle. If it appears unstable. Deflate and try again. "Lift an inch, shore an inch"	3
Air Fittings	Bent or broken	Unable to inflate bag and perform rescue operation	2	Pre and post mission inspections. Make sure the system is fully functional before leaving.	3
Hose	Bursts	Unable to inflate bag and perform rescue operation	2	Use anti burst tape or FIBERFIX to repair leak fo operations.	3